APPENDIX 3.6.5

GENERAL GUIDELINES FOR THE DISPOSAL OF CARCASSES

Introduction

The mass destruction and disposal of animals in the event of an animal disease outbreak are always subject to intense public and media scrutiny thereby obligating the *Veterinary Administration* of a Member Country to not only conduct carcass disposal operations within acceptable scientific principles to destroy the causative pathogen of disease but also to satisfy animal welfare, public and environmental concerns.

The guidelines in this Appendix are general and generic in nature. They are recommended for adoption after consideration of the application best suited to prevailing circumstances of a specific disease outbreak. The choice of one or more of the recommended technologies should be in compliance with the mandates provided for within relevant local and national legislation and be attainable with the resources available within the Member Country. The guidelines should also be read and applied in conjunction with the procedures described for the humane killing of animals in Appendix XXX of the *Code*.

The chapter aims to briefly describe the definitions applicable to the disposal of carcasses, outline the regulatory and jurisprudence requirements that should be considered, identify the most important risk factors associated with the disposal of carcasses, list the social factors and practical considerations relevant to carcass disposal, give guidelines on appropriate technologies that could be applied and give guidance on the decision-making process in electing the most appropriate technology for the disposal of carcasses under specific circumstances.

Where indicated within the relevant chapters of the *Code,* the vaccination of animals in combination with or without a stamping-out policy to contain a disease outbreak could be the preferred choice above mass destruction. The eventual decision to embark on the mass destruction and disposal of animals to contain a disease outbreak should be carefully evaluated against available alternatives, environmental, socio-political and socio-economical concerns, trade implications as well as prevailing ethical and ethnic beliefs and preferences.

Definitions

For the purpose of this Appendix the following definitions relevant to the disposal of carcasses shall apply:

- **Carcass -** means the body of an animal subsequent to euthanasia or death that requires safe destruction.

- **Disposal -** means the inactivation of the pathogen with reduction of the carcass and related materials to constituent components.

- **Technology -** means the process by which disposal is achieved.

- **Transport -** means the bio-secure removal of animals or carcasses or material from the site of infection to the site of disposal.

- **Bio-security -** means the absolute containment of infection.

- **Human safety -** means elimination of risks to the health and well-being of the persons involved in animal disposal procedures.

- **Animal welfare -** means reference to guidelines established for humane killing as defined in Appendix XXX.

- **Mass destruction -** means an emergency destruction and disposal of a large number of animals for disease control purposes

Regulations and jurisdiction

The laws regulating animal health, prevention and eradication of animal diseases, and the organisation of the *Veterinary Administration* should give the *Veterinary Services* the authority and the legal powers to carry out the necessary activities for an efficient and effective disposal of carcasses. For most of the disposal options, legislation of other governmental bodies at national or local level is in force and should be respected. Therefore close co-operation between the *Veterinary Service* and these authorities is indispensable to develop a coherent set of legal measures for carcass disposal in peace time in order to apply these undisturbed where and when it is necessary. In this context the following aspects should be clearly regulated:

- Right of entry on a farm and its premises for personnel of the *Veterinary Service* and of contractors working for the *Veterinary Service*.

- Total movement ban to be applied on an infected or suspected farm and the authority to make exemptions under certain bio-security conditions - for instance for transport of carcasses to another location for disposal..

- The obligation for the involved farmer, his relatives and his personnel to co-operate with and to apply all the measures ordered by the *Veterinary Service*.

As regard to infected and suspected animals and their products:

  - the transfer of the ownership of these to the competent authority (for instance through confiscation or buying up with compensation of the farmer) and

  - the right to kill these animals on the farm or wherever the *Veterinary Service* determines.

If burning of the carcasses is the option of choice:

  - the Veterinary Service should have the authority to determine the place where the pyre is situated,

  - national and local governmental organisations competent for the protection of the environment should have given their approval for this solution in advance and should have adopted the necessary legal framework to allow this and

  - all involved authorities should have determined on the conditions for removal of the ashes.

If mass burial, mounding or open farm burial is the preferred option:

- the Veterinary Service should have the authority to determine the place of burial in accordance with other involved authorities,

national and local governmental organisations competent for the protection of the environment and subsoil water reserves should have agreed with this solution and should have adopted the necessary legislation and

- all involved authorities should have determined together the regime applicable to the site after the burial.

If rendering or any other centralised processing is the preferred option:

- the Veterinary Service should have the authority to require the necessary capacity at the processing company and to determine priorities,
- national and local governmental organisations regulating these types of processing should have agreed with the increased production volumes and other related consequences beforehand and should have covered the legal aspects and
- all involved authorities should have determined on the conditions applicable to the products from these carcasses.

It might happen that the chosen option for carcass disposal has to be applied near the border of a neighbouring country. In such cases the competent authorities of this country should be consulted and common legal solutions should be found in order to prevent misunderstanding and conflict.

If there is insufficient capacity in the country for processing of carcasses and if other options for carcass disposal are also limited, a solution could be the processing in another country. However, when an outbreak of an infectious animal disease occurs in a country, governments take preventive measures against import of potentially infected animals and products from the infected region. Those measures will also prevent the importation and transport of carcasses to a processing plant. If the export option is the choice, the conditions should be well established between the two involved countries and all legal aspects cleared beforehand. It should be realised that strong opposition can be expected from the farming community in the importing country against such transports. An agreement and preparation of the necessary legal aspects in peace time will help to apply this solution rapidly when it is needed. Clear communication about the process to be followed will help to elicit public support.

Pre-outbreak activities

The decision to embark on the mass destruction and disposal of animals in the event of a major disease outbreak or the mass disposal of animals in the event of natural disasters such as floods, and the implementation of the decision, need often to be taken in a short limit of time and activities to execute the decision, must similarly proceed with the minimum delay. The success or failure however, is primarily determined by the structures, policies and infrastructure that were established and agreed upon well in advance of such an event within contingency plans and working relationships and responsibilities established in preparation with other supportive structures.

- *Technical preparedness* – implies a predetermined decision process enunciated in a document, training of staff in the technical aspects of applicable technologies and the development of instructional manuals such as standing operating procedures (SOP's) for events of disposal. The sensitivity and public scrutiny on the process of carcass disposal requires that a trained

and competent official must be available on site. Such an official must be familiar with procedures to conduct the chosen technologies for carcass disposal.

Financial preparedness - the factors of a compensation mechanism to assist affected producers; access to emergency funding permitting rapid and effective action; and access to an expanded human resource through agreements with private veterinarians, are considered critical to the success of the program. To be effective, these factors must be considered, resolved and in place prior to a disease occurrence. Transparency on the criteria for compensation and the minimum delay in the execution of payments are critical factors to ensure cooperation from affected farmers.

- *Pre-established partnerships* - a relationship with industry is essential to obtain compliance with animal health policies. Partnerships should not only include farmer associations or commodity representatives but also animal welfare organisations, supportive structures such as security services, disaster management units within government structures, the media and consumer representative groupings. This relationship is encouraged and essential to enhance the receptivity to future risk communications. In some countries tourism is a very significant contributor to the national economy and can be adversely affected by animal disposal and emergency operations.

- *Communication plan* - the *Veterinary Administration* must accept that the information on any event of mass culling and disposal of animals cannot and should not be withheld from public scrutiny. Sharing the information based on scientific facts on an ongoing basis is essential. Information sharing with politicians and the media is especially important but information sharing with officials involved in the outbreak, affected farmers and professional organizations is equally essential but often neglected or forgotten. A well informed and knowledgeable spokesman should be available at all times to answer questions from the media and the public. Consistency in the information given is essential and should be guided by an available set of pre-empted well debated questions and answers that should be daily updated. An essential pre-requisite is to ensure ownership by politicians for the policies applied for the mass destruction and disposal of animals to contain a disease outbreak. The support by politicians should already be established in policy formulation and budgetary processes by the *Veterinary Administration* of the Member Country.

- *Equipment* – a supply of essential emergency equipment should be available immediately while contracts with rendering plants should be established as a default standing arrangement. The management of equipment should include provisions for expansion, temporary storing facilities, transport, and transport on farm, drivers, disinfection, mobile handling facilities for animals such as mobile crush-pens, protective and disposable material and logistical support. Procurement procedures should be simplified and special authorizations provided for the operation to enable the minimum delay in obtaining essential equipment and to supplement or replace existing equipment. Equipment would also include the type of burning material used for pyre burning of carcasses. In some countries sufficient wood would still be available but usage thereof is subject to environmental legislation and environmental concerns. Old vehicle tyres are a cheap and readily accessible alternative to wood but could be a source of environmental pollution and should only be used if sanctioned by applicable local or national legislation. The prior identification of sources of burning material are therefore essential so that it could be obtained with the minimum loss of time and effort when needed.

- *Transport arrangements* – The transport needed during mass disposal of animals are generally not included in the normal stock of vehicles of a *Veterinary Administration.* Heavy trucks,

tractors, bulldozers, front-end loaders and the like, are all types of vehicles needed for transport of animals, collection of burning material, filling and closure of disposal sites and transport from the farm to a disposal site. It is important to ensure that the vehicles used do not pose a source for dissemination of the infection.

Risk factors

The list of risk factors has not the pretension to be complete. Other risk factors may influence the choice of a technique for carcass disposal as well.

- ***Speed*** - early detection of new infections, immediate killing of infected animals and rapid removal of the carcasses with inactivation of the pathogen are of utmost importance for the eradication of infectious diseases. Viral pathogens will not further multiply after the host is killed, but active and passive spread of the pathogen from the carcasses and their surroundings should be blocked as soon and as effectively as possible.

- ***Occupational health safety*** - carcasses in decomposition soon become a health risk for the persons who have to handle them during the process of disposal. Disposal should be organised in such a way that the workers are safeguarded against the risks of handling decomposed dead bodies. However special attention should be given to zoonotic aspects of certain pathogens as for instance avian influenza. Workers should be sufficiently protected against infection with a zoonotic pathogen (protective clothing, gloves, face masks, spectacles, vaccination, anti viral medicines, regular health checks).

- ***Pathogen inactivation*** - the chosen disposal procedure must give optimal safety as regards to the inactivation of the pathogen. If this cannot be achieved instantly, the spreading of the pathogen from the process should be blocked. Scientific information about the reduction of the pathogenic agent over time under the expected climatological conditions for any of the technologies should be the basis for the lifting of restrictions for the products or sites

- ***Environmental concerns*** - the different technologies for carcass disposal have different effects on the environment. For instance pyre burning will produce smoke and smells; burial might lead to gas production; escape of these gases and as a result smell; but also risk of contamination of air, soil, surface and sub surface water. Increased operating hours or increased throughput in a rendering plant may lead to increased smell or disturbances in the normal functioning of the waste water treatment and other protective facilities of the plant.

- ***Availability of capacity*** - practically all the technologies for carcass disposal have limitations on capacity. When the number of carcasses to be disposed of is high, the capacity of the acceptable technologies will soon be the bottle neck. An assessment of possibilities and capacities in peace time is very important to be able to take quick decisions in case of emergency. Temporary storage of carcasses in cold stores could sometimes relieve the lack of processing capacity.

- ***Cost*** - technologies for carcass disposal and specially those using sophisticated equipment are very costly. Budgetary provisions should be made for emergencies. When the Veterinary Service during a disease outbreak seeks the cooperation of private companies offering the needed capacity, the costs might escalate tremendously. Therefore it is necessary to negotiate a contract in peace time with those suppliers about capacities and costs when preparing a strategy for eradication.

- ***Public reaction*** - carcass disposal can easily lead to adverse reactions from the public when pictures of half burned or hoisted carcasses are shown on TV or in press. Urbanised

populations estranged from rural practices will react often very emotionally on these images. In poorer countries the destruction of valuable meat of not yet sick animals may provoke public misunderstanding.

Acceptance by farmers - the owners of an infected farm will in general prefer technologies at a distance and not on their own farm. Farmers outside an infected zone will prefer disposal within the infected area. All farmers will be very sensitive with regard to the safety measures taken to prevent spread of the disease by the used technology and the transport of the carcasses to the processing plant or disposal site. Proper compensation of owners for the loss of their animals or for the disposition of burial or burning sites will improve acceptability.

- ***Transport*** - for the application of all technologies for disposal, cranes, shovels and trucks must be used to transport the carcasses. This equipment can transfer the infection to other farms. Cleaning and disinfection of the outside surfaces of these vehicles when leaving an infected premise should receive special attention. The hygiene of the driver, his cabin, his lockers and his clothing and footwear should also be part of this process. The trucks transporting carcasses should be leak proof and be completely covered in order to prevent spread of the pathogen from the truck. The Veterinary Service should supervise the departure of the vehicle from the farm, the route the transport passes and the arrival at the disposal plant or site.

- ***Wildlife*** - many infectious diseases can affect wild animals as well as domesticated animals. Sometimes farm animals become infected through contact with game, but the population of wild animals might also become infected from an outbreak of a disease on a farm. When disposing of carcasses full attention should be given to the prevention of contamination of wildlife. Predators could try to get access to dead carcasses which might cause active or passive spread of the infection to other wild or domesticated animals.

Social factors related to carcass disposal

Culling and destroying of animals for the eradication of infectious disease often produce vehement reactions from the public. Reactions can be expected from the owners of animals which have to be culled, from farmers who are scared that their animals might contract the disease, animal welfare advocates who try to protect the lives of animals, people who abhor pictures of the culling of animals and the transport, burning and burial of carcasses, organisations who fight for environmental protection, culling perceived as a waste of edible food, etc.

In general a stamping out policy is applied to defend the export interests of the animal husbandry industry and is economically motivated. However, in some countries the general public and politicians express their doubts or their opposition against economical reasons as the leading argument to apply this strategy.

Even not all farmers will support the economic necessity of stamping out. For many farmers the rapid regaining of export markets is of no interest. Animals often represent a much more important and differentiated value than pure economics. For an animal breeder his animals represent a professional achievement based on the skills of himself and his ancestors. Many hobby farmers consider their animals as personal companions. In traditional communities animals are kept not for production but for a variety of reasons like a beast of draught or burden, for ceremonial reasons or as a symbol of wealth. For some religions the killing of certain animals is not acceptable. The export related economic argument will fail to convince such owners of the need for culling especially when animals, not showing any symptoms of disease but identified as carriers or serological positive, are included in the culling operation. Loss of certain animals cannot be compensated financially.

Practical considerations

In addition to the risk factors and pre-outbreak activities identified above, several practical issues, often not considered or often accepted as obvious but not attended to, need to be noted. The list is not exhaustive but gives an indication of some of the easily forgotten but essential considerations:

Selection of disposal site – sufficient top soil to cover the site; water drainage; prevailing wind conditions; easy access to transport; availability of meteorological data; separation from sensitive public sites.

- ***Selection of contractors for transport –*** availability; can they supply in all the needs; exclusive use of vehicles or would they also be used for other purposes (risk of disease transmission); access to available roads; suitable for the purpose to be used.
- ***Logistical preparedness for the appropriate technology*** – availability of burning material (wood, old tyres); sufficient manual labour available; sites and availability of disinfection tents for personnel; storage and disposal of protective clothing; housing for personnel to prevent them from going back to home and spread infection; facilities for entry and exit control; availability of electricity for night operations; personal facilities for personnel such as toilets, drinking water; availability of communication – mobile phone reception; protection (eg vaccination) of personnel; rendering capacity at rendering plants; additional cold storage and holding facilities at rendering plants and abattoirs; availability of freezing facilities before rendering.
- ***Procedures and policies for disposal of other products*** – manure, eggs; milk; non-animal products; animal feed.
- ***Wildlife*** – do they pose a risk in the immediate environment; expertise availability for culling of wildlife; availability of capture teams?

Recommended technologies for the disposal of carcasses

These technologies are presented as a hierarchy based on their reliability for pathogen inactivation.

- ***Rendering -*** This is a closed system for mechanical and thermal treatment of animal tissues leading to stable, sterilized products, e.g. animal fat and dried animal protein. It grinds the tissue and sterilizes it by heat under pressure. The technology exists in fixed facilities and is in normal usage. It produces an effective inactivation of all pathogens with the exception of prions where infectivity is reduced. A medium sized rendering plant could process 12 tonnes per hour of operations. The availability of the capacity should be determined in advance. Such a plant can operate within environmental standards.
- ***Incineration -*** This technology can be applied as:
    - Fixed, whole-carcass incineration,
    - Mobile air curtain whole carcass incineration,
    - Municipal incinerators,
    - Co-incineration

  Fixed whole carcass incineration occurs in an established facility in which whole carcasses or carcass portions can be completely burned and reduced to ash. Effective inactivation of pathogens is produced. Without additional technology, the exhaust emissions are not subjected to environmental control. However these emissions can be subjected to air scrubbing procedures to meet environmental standards. Fixed facility incineration has been

used to dispose of BSE infected carcasses, as well as rendered meat-and-bone meal (MBM) and tallow from cattle carcasses considered to be at risk of BSE. Fixed facility incineration is wholly contained and usually highly controlled. It is typically fuelled by diesel, natural gas, or propane. The exhausts may be fitted with afterburner chambers to completely burn hydrocarbon gases and particulate matter from the main combustion chamber. Whole carcass disposal can be problematic given the batch-feed requirements at most biological waste incineration plants. Many waste incineration facilities refuse whole animals which are 70% water, but prefer waste of 25% water. Therefore, combining rendering and incineration is a promising approach. The resultant ash is less problematic and is considered safe. Although this is a more controlled procedure, there is still a potential fire hazard.

Municipal incinerators are pre-established facilities which are normally used for the burning of household or industrial waste. They may not be currently licensed to burn carcasses.

Co-incineration is a process in which meat and bone meal, carcasses or parts of carcasses are burned in conjunction with other substances such as hazardous waste incineration, clinical waste incineration, and other industrial incinerations such as power plants, cement kilns, blast furnaces and coke ovens. In practice meat and bone meal has been used as a secondary fuel on a large scale in cement kilns and power plants.

Air curtain incineration - air curtain incineration involves a machine that fan-forces a mass of air through a manifold, thereby creating a turbulent environment in which incineration is accelerated up to six times faster than open-air burning. The equipment for this process can be made mobile which can be taken on-site but the potential fire hazard must be considered. Because it can be used on site, there is no requirement for transportation of the animal material. It also produces effective inactivation of pathogens and may actually achieve higher temperatures (1000 ^{0}C). Fuelled by diesel engines, high velocity air is blown into either a metal refractory box or burn pit. The materials required are wood (in a wood:carcass ratio of from 1:1 to 2:1), diesel fuel for both the fire and the air-curtain fan, and properly trained personnel. For incineration of 500 adult swine, the requirements are 30 cords of dry wood and 200 gallons of diesel fuel. The product is ash. Since the procedure is not wholly contained, it is subject to variable factors such as human operation, weather, and local community preferences.

Pyre burning - this is an open system of burning carcasses either on-farm or in collective sites fuelled by additional materials of high energy content. This is a well established procedure that can be conducted on site with no requirement for transportation of the input material. However, this process could be contrary to environmental standards for air, water and soil. It takes an extended period of time and has no verification of pathogen inactivation. In fact, there is a possibility of particulate transmission from incomplete combustion. Further, because the process is open to view, there is a negative reaction and lack of acceptance by the public.

Comparison of incineration methods

With all three incineration methods described above, the greater the percentage of animal fat, the more efficiently a carcass will burn. (Swine have a higher fat content than other species). For fixed facility incinerators, the capacity depends on the chamber's size and can range from 50 kg / hour up to 10 tonnes of poultry carcasses / day. Preprocessed, relatively homogeneous carcass material is more easily handled than large numbers of whole animal carcasses. Depending on the design and on-site management, air-curtain incinerators can burn 4 - 6 tons of carcasses / hour.

- ***Open-air burning*** can be relatively inexpensive, but it is not suitable for TSE infected carcasses. It is labour and fuel intensive, and dependent on favourable weather. It has environmental problems and a poor public perception. It is generally accepted that open-air burning pollutes. Although this is dependent on a number of factors. This may be more perception than established fact. Open air burning can also pose significant public perception, psychological, and economic problems

- ***Fixed facility incineration*** destroys TSE infected carcasses and is highly biosecure. However it is expensive and difficult to operate and manage from a regulatory perspective. Properly operated fixed facility incineration pose fewer pollution concerns

Air-curtain incineration is mobile, usually environmentally sound, and suitable for combination with debris removal. However it is fuel intensive, logistically challenging, and is not validated to dispose of TSE infected carcasses. Air curtain technology in general has been shown to cause little pollution with fire boxes burning cleaner than trench burners. It has higher combustion efficiencies with less carbon monoxide and particulate matter emissions.

- ***Composting -*** carcass composting is a natural biological decomposition process that takes place in the presence of oxygen. In the first phase, the temperature of the compost pile increases, organic materials break down into relatively small compounds, soft tissue decomposes, and bones soften partially. In the second phase, the remaining materials, mainly bones, break down fully to a dark brown or black humus containing primarily non-pathogenic bacteria and plant nutrients.

  Composting systems require a variety of ingredients including carbon sources, bulking agents and biofilter layers. Carbon sources can include materials such as sawdust, straw, cured cornstalks, poultry litter, ground corn cobs, wheat straw, hay, shavings, paper, leaves, vermiculite, and matured compost. A 50:50 mixture of separated solids from manure and a carbon source can be used as a base material for carcass composting. The finished compost retains nearly 50% of the original carbon source which can be recycled in the compost process. A carbon:nitrogen (C:N) ratio in the range of 25:1 - 40:1 generates enough energy and produces little odour during the composting process. As a general rule the weight of carbon source materials to mortalities is approximately 1:1 for high C:N materials such as sawdust, 2:1 for medium C:N materials such as litter and 4:1 for low CN materials such as straw.

  Bulking agents have bigger particle sizes than carbon sources and maintain adequate air spaces (around 25-35% porosity) within that compost pile by preventing packing of materials. Bulking agents include spent horse bedding, wood chips, rotting hay bales, peanut shells, and tree trimmings. The ratio of bulking agents to carcasses should result in a bulk density of the final compost mixture that does not exceed 600 Kg/m^3. The weight of the compost mixture in a 19 litre bucket should not be more than 11.4 kg.

  A biofilter is a layer of carbon source or bulking material that enhances microbial activity with proper moisture, pH, nutrients, and temperature. It deodorizes gases released at ground level and prevents access by insects and birds thus minimizing transmission of disease agents.

The site selection criteria include a well drained area at 90 cm above the high water table level, at least 90 metres from sensitive water resources, and an adequate slope (1-3%) to

allow proper drainage and prevent pooling of water. Runoff should be collected and treated. The location should be downwind of nearby residences. The site should have full accessibility but have minimal interference with other operations and traffic. Storage time of mortalities should be minimized. Co-composting materials should be ground to 2.5 - 5.0 cm and mixed. Compost materials should be lifted and dropped rather than be pushed into place. Compost piles should be covered by a biofilter layer during both phases of composting. The moisture content of the carcass compost pile should be 40-60% (wet basis).

A temperature probe should be inserted straight down into each quadrant of the pile and internal temperatures should be monitored daily and weekly during both phases of composting. During the first phase, the temperature at the core of the pile should rise to at least 55-60 ^{o}C within 10 days and remain there for several weeks. A temperature of 65^{o}C at the core, maintained for 1 - 2 days, will reduce pathogenic bacterial activity and weed seed germination. However spore formers such as *Bacillus anthracis* and other pathogens such as *Mycobacterium tuberculosis* will survive. Proper aeration is important in maintaining uniform temperature and moisture content throughout the pile. After the first phase of composting, the volume and weight of the pile may be reduced by 50-75%. Following the first phase, the entire compost pile should be mixed, displaced and reconstituted for the secondary phase. If necessary, moisture can be added.

The end of the second phase is marked by an internal temperature of 25-35^{o}C, a reduction in bulk density of approximately 25%, a colour of dark brown to black and the lack of an unpleasant odour. Although heat generated during carcass composting results in some microbial destruction, it is not sufficient to completely sterilize the end product. Pathogenic bacterial activity is reduced when the temperature in the middle of the pile reaches 65 ^{o}C within one to two days. An average temperature of 55-60 ^{o}C for a day or two reduces pathogenic viruses, bacteria, protozoa (including cysts) and helminth ova to an acceptably low level, but endospores produced by spore-forming bacteria would not be inactivated.

- ***Trench burial and mass burial -*** this is a system to deposit whole carcasses below ground level and to be covered by soil, with no additional inactivation of pathogens. It is an established procedure which if conducted on site does not require transportation and is used to control the spread of disease. It does however require an environmental assessment because of the potential contamination of groundwater, or of aquifers if leachate is not controlled. Further, it does not inactivate all pathogenic agents.

- ***Licensed commercial landfill -*** this process involves deposition of carcasses in predetermined and environmentally licensed commercial sites. Because the site has been previously licensed, all environmental impacts such as leachate management, gas management, engineered containment, flooding and aquifers have already been considered. However, the area is open and uncovered for extended periods, there is a potential emission of aerosols, and there is resistance from the public to such an approach.

- ***Mounding -*** this process is one of mass burial above ground and it has similar considerations to those of mass burial and composting.

- ***Fermentation -*** this process is a closed system of anaerobic microbiological decompositions which requires prior mechanical and thermal treatment and which results in the production of biogas. This process does not inactivate pathogens, but typically uses non-dried rendered product as the input material.

- ***Alkaline hydrolysis -*** alkaline hydrolysis uses sodium hydroxide or potassium hydroxide to

catalyse the hydrolysis of biological material into a sterile aqueous solution consisting of small peptides, amino acids, sugars, and soaps. Heat is applied (150°C) to accelerate the process. The only solid byproducts are the mineral constituents of the bones and teeth of vertebrates. This residue (2% of the original weight of the carcass) is sterile and easily crushed into a powder. The temperature and alkali conditions of the process destroy the protein coats of viruses and the peptide bonds of prions. Both lipids and nucleic acids are degraded. Significantly large carbohydrate molecules, such as cellulose, although sterilized by the process, are not digestible by alkaline hydrolysis eg paper, string, undigested plant fibres, and wood shavings.

The process is carried out in an insulated steam-jacketed, stainless steel pressure vessel with a sealed lid. The vessel operates at 70psig to achieve 150°C. The process does not release any emissions into the atmosphere and only causes minor odour production. The end product solution can be released into the sanitary sewer with proper monitoring of pH and temperature according to guidelines. The total process time for alkaline hydrolysis digestion of carcass material is 3-8 hours depending on the disease agent eg bacterial and viral contaminated waste (4 hours), transmissible spongiform encephalopathy waste (6 hours). A mobile trailer unit has a capacity of digesting 4000 pounds of carcasses every 8 hours.

- ***Lactic acid fermentation*** - lactic acid fermentation is a means to preserve carcasses up to 25 weeks until they can be rendered. Fermentation is an anaerobic process. Carcasses are ground to fine particles, mixed with a fermentable carbohydrate source and a culture inoculant, and added to a fermentation container. For lactic acid fermentation, lactose, glucose, sucrose, whey, whey permeates, and molasses are suitable carbohydrate sources. The carbohydrate source is fermented to lactic acid by *Lactobacillus acidophilus*.

  Under optimum conditions with a temperature of about 35 °C, the pH of fresh carcasses is reduced to less than 4.5 within two days. Some microorganisms are destroyed by the acid pH while the remainder will be destroyed by heat during rendering.

- ***Anaerobic digestion*** - this process is suited for large-scale operations. It reduces odours and reduces pollution by greenhouse gases due to the combustion of methane. It can eliminate carcasses and at the same time produce energy but may require size reduction and sterilization of carcasses on-site before applying anaerobic technology. Anaerobic digestion transforms waste into fertilizer. Although anaerobic digestion is less expensive with mesophilic organisms at 35°C, the use of thermophilic organisms at 55 °C is preferred because the additional heat destroys some pathogens. It is necessary to use additional heat treatment at the end of the process to fully inactivate pathogens however, even with this, prions are not inactivated. Carcasses have a higher nitrogen content than most other wastes and therefore result in a high ammonia concentration which can inhibit anaerobic digestion. This limits the loading rate for anaerobic digesters that are treating carcass wastes.

- ***Non-traditional and novel technologies***

  - ***Pre-processing*** - this involves on farm pre-processing prior to transportation of carcasses to central facilities because of the complexity and cost (eg rendering or incineration). Preprocessing could include the grinding of carcasses. (A large portable grinder can grind up to 15 tons of animal carcasses per hour). This could then be transported in sealed containers, or be subjected to fermentation or freezing. The primary objectives are to minimize on-site contamination risks and to maximize the number of options for disposal.

- ***Carcass disposal at sea -*** disposal in a coastal sea or on a continental plateau cannot occur without the authorization of the coastal State which must make a regulation on the dumping and which must consult with other neighbouring States. International Conventions express a fundamental principle which countries should be obliged to respect even if they are not signatories. These Conventions do not directly prohibit disposal of carcasses at sea, but do define the conditions to be met. It is possible for this disposal if it is technically and scientifically proven that the products to be disposed are not harmful, and if the State has authorised this disposal with a permit.

Bio-refining - this is a high pressure, high temperature hydrolytic process, conducted in a sealed pressurized vessel. The waste material is treated at 180 ^{o}C at 12 bar pressure for 40 minutes, heated by indirect steam application to the biolytic reactor. The process can accommodate whole animal carcasses, MBM, food processing wastes, other compostable material, paper and comparable materials, and cereal straws either alone or in combination. In the dehydration cycle, the steam water is condensed and either used for other purposes or discarded. Each cycle lasts four hours. The capacity of each reactor is 20,000 tonnes of raw material per year. The process inactivates all microbiological agents. It is currently under evaluation for its efficiency in inactivating the prions of transmissible spongiform encephalopathies.

Special considerations for prion diseases

One of the problems in demonstrating the effectiveness of the inactivation of prions is the lack of a simple, rapid and inexpensive test for the presence of the infective agent, especially at low concentrations. The ultimate test is bioassay in a sensitive detector species by an efficient route, but usually this is only relevant in research. Typically this is done using panels of mice bred to be susceptible to particular types of transmissible spongiform encephalopathies (TSEs). However it must be recognized that the mouse to cattle species barrier has been demonstrated to be 500, therefore affecting sensitivity.

Although rendering at 133^{0}C and three bars of pressure for 20 minutes is a defined standard, reductions of infectivity by this technology are in the order of 1:200 – 1:1000. Commercial incinerators have an inactivation rate of one million fold, while burning on pyres has a reduction rate of 90 %. (It should be noted that pyres are not suitable for sheep because of the wool and fat.) Alkaline hydrolysis produces a 3-4 log reduction in infectivity over a three hour period. Landfill and deep burial are suggested to have a reduction in infectivity of 98 – 99.8 % over three years. Based on this information, rendering, incineration, and alkaline hydrolysis are the most reliable technologies at this time. The significance of small amounts of infectivity become evident when you consider that experimentally it has been shown that exposure of sensitive species to as little as 1.0, 0.1 or even 0.01 grams of infected nervous tissue can induce infection.

Given all of the above (except complete burning in closed furnaces), it must be recognized that no process has been demonstrated to be 100 % effective in removing TSE infectivity and there will be some residual levels of infectivity remaining after treatment.

Guidelines for decision-making for the disposal of carcasses

Strategies for carcass disposal require preparation well in advance of an emergency in order to maximize the efficiency of the response. Major issues related to carcass disposal can include the number of animals involved, bio-security concerns over movement of infected and exposed animals, people and equipment, environmental concerns, and the extreme psychological distress and anxiety

experienced by producers and emergency workers.

The disposal of large numbers of carcasses will be expensive. As well, fixed and variable costs will vary with the choice of the disposal method. Each method used will result in indirect costs on the environment, local economies, producers, and the livestock industry. Decision makers need to understand the economic impact of various disposal technologies.

A disposal option hierarchy may be incapable of fully capturing and systematizing the relevant dimensions at stake, and decision makers may be forced to consider the least preferred means. It therefore requires a comprehensive understanding of any array of carcass disposal technologies and must reflect a balance between the scientific, economic, and social issues at stake. Timely slaughter, maintenance of security and prevention of further spread of disease, are the essential considerations in terms of disease control.

- ***Process for decision- making***:

  The following is an example of a possible process for aiding decision-making by comparing the suitability of various disposal options against factors that are considered important for the specific disposal event in question.

  Step 1 - Define the factors to be considered. Include all relevant factors and allow enough flexibility to permit modifications for different situations and locations. Examples of possible factors include operator safety; community concerns; international acceptance; transport availability; industry standards; cost effectiveness and speed of resolution. These factors can be modified or changed, as is shown in the following example, to best fit the situation of event involved.

  Step 2 - Assess the relative importance of the factors by weighting each on their considered importance to addressing the event in question. The sum of all the weightings, regardless of the number of factors, must total 100.

  Step 3 - Identify and list all disposal options under consideration. Rate each disposal option against each factor and assign a Utility Rating of between 1 to 10 to each comparison. The Utility Rating (U) is a number between 1 and 10 which is allocated according to how well the option achieves the ideal with respect to each factor, (eg 1 = the worst possible fit, and 10 = the best fit).

  Step 4 - For each factor and each disposal option, multiply the Factor Weight (F) x Utility Rating (U) to yield a numeric Balanced Value (V), (eg V = F x U)

  Step 5 -By adding the Balanced Values to a sum for each disposal option, it is possible to compare the suitability of disposal options by numerically ranking the sums of the Balanced Values for each disposal option. The largest sum would suggest that disposal option as the best balanced choice.

  Example - An example of the use of this process follows in Table 1. In this example rendering achieved the highest sum and would be considered as the best balanced choice and the most suitable disposal option for the factors considered.

Table 1: **Decision Making Process**

Method	Rendering	Fixed Incineration	Pyre Burning	Composting	Mass Burial	On-Farm Burial	Commercial Landfill

Method		Rendering		Fixed Incineration		Pyre Burning		Composting		Mass Burial		On-Farm Burial		Commercial Landfill	
	Weight	Utility	Value	Utility	Value	Utility	Value	Utility	Value	Utility	Value	Utility	Value	Utility	Value
Factors															
Operator Safety	20	7	140	4	80	8	160	3	60	7	140	8			
Speed of Resolution	20	8	160	8	160	2	40	5	100	5	100	6			
Pathogen Inactivation	15	10	150	10	150	8	120	5	75	4	60	4			
Impact on Environment	10	10	100	8	80	3	30	10	100	3	30	3			
Reaction of the Public	10	10	100	7	70	1	10	9	90	3	30	4			
Transport Availability	5	1	5	1	5	8	40	5	25	3	15	8			
Acceptable to Industry	5	7	35	7	35	7	35	7	35	6	30	7			
Cost	5	4	20	1	5	6	30	9	45	8	40	9			
Risk to Wildlife	5	10	50	10	50	5	25	4	20	5	25	5			
Capacity to Meet Requirements	5	5	25	3	15	9	45	9	45	9	45	9			
Total Weight to Equal 100 Units	100	sum	785	sum	650	sum	535	sum	595	sum	515	sum		sum	